Journal of the Royal Society of Arts

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FORTHCOMING MEETINGS

MONDAY, 21ST FEBRUARY, at 6 p.m. The last of three CANTOR LECTURES on '*Some Aspects of Music*', entitled '*Music in Medicine*', by Frank Howes, M.A., F.R.C.M., Music Critic of *The Times*. (The lecture will be illustrated with gramophone records.)

WEDNESDAY, 23RD FEBRUARY, at 2.30 p.m. FERNHURST LECTURE. '*Virus Diseases of Plants*', by F. C. Bawden, M.A., F.R.S., Deputy Director and Head of the Plant Pathology Department, Rothamsted Experimental Station. Sir James Scott Watson, C.B.E., M.C., LL.D., D.Sc., lately Chief Scientific and Agricultural Adviser, Ministry of Agriculture, will preside.

THURSDAY, 24TH FEBRUARY, at 5.15 p.m. COMMONWEALTH SECTION. '*Music in Africa*', by S. Hylton Edwards, Assistant Director of Music, St. John's College, Johannesburg. Edric Cundell, C.B.E., Principal, Guildhall School of Music and Drama, will preside. (The paper will be illustrated with the aid of piano and gramophone. Tea will be served from 4.30 p.m.)

WEDNESDAY, 2ND MARCH, at 2.30 p.m. '*Business as Patron of the Arts in the Industrial Age*', by F. C. Hooper, B.Sc., Managing Director, Schweppes, Ltd. Sir Francis Meynell, Master of the Faculty of Royal Designers for Industry, will preside.

THURSDAY, 3RD MARCH, at 5.15 p.m. COMMONWEALTH SECTION. '*Anthropology in Central Africa*', by Max Gluckman, M.A., D.Phil., Professor of Social Anthropology, University of Manchester. I. Schapera, M.A., D.Sc., Professor of Anthropology, University of London, will preside. (Tea will be served from 4.30 p.m.)

WEDNESDAY, 9TH MARCH, at 2.30 p.m. '*The Beauty of Stained Glass*', by Carl Edwards. The Right Honble. Lord Mottistone, F.S.A., F.R.I.B.A., D.L., will preside. (The paper will be illustrated with lantern slides and examples of work.)

THURSDAY, 10TH MARCH, at 7.30 p.m. FILM EVENING. (See special notice on page 188.)

MONDAY, 14TH MARCH, at 6 p.m. The first of three CANTOR LECTURES on '*The Mechanical Properties of Metals*', entitled '*Tensile Properties*', by Hugh Ford, D.Sc., Ph.D., M.I.Mech.E., Professor of Applied Mechanics, Imperial College of Science and Technology. (The lecture will be illustrated with lantern slides.)

WEDNESDAY, 16TH MARCH, at 2.30 p.m. ALFRED BOSSOM LECTURE. '*English Church Architecture*', by A. B. Knapp-Fisher, F.R.I.B.A., F.S.A., Hon.A.R.C.A. Sir Alfred Bossom, Bart., F.R.I.B.A., M.P., a Treasurer of the Society, will preside.

THURSDAY, 17TH MARCH, at 6.30 p.m. DISCUSSION on '*The Future of Shop Design and Window Display*'. Opening speaker: John Gloag, Hon.A.R.I.B.A., a Vice-President of the Society. (Full details will be announced later.)

Fellows are entitled to attend any of the above meetings without tickets and may also bring two guests. When they cannot accompany their guests, Fellows may give them special passes, books of which can be obtained on application to the Secretary.

FILM EVENING

The next Film Evening will be held on Thursday, 10th March, at 7.30 p.m., and the programme will consist of the following films: *Steel and Atomic Energy*, *Power to Fly*, *Slice of Life*, and *Ant Warfare*.

Steel and Atomic Energy (16 minutes) was produced for the British Iron and Steel Federation and is a new film about a new industry—the creation of power from atomic energy—with which the steel industry has been largely concerned from its inception. The film will be introduced by the producer, Mr. Frank Green.

Power to Fly (18 minutes), which is in Technicolor, was produced by Halas & Batchelor Cartoon Films, Ltd., for the British Petroleum Company Ltd. The film tells the story, in cartoon form, of the development of flight from the time of Leonardo da Vinci to the present day. It will be introduced by the producer, Mr. Allan Crick.

Slice of Life (25 minutes) was produced for the National Association of British and Irish Millers, and tells the story of bread from the growth of the wheat to the baking of the loaf. It contains interesting and attractive photographs from many parts of the world, and will be introduced by Mr. C. L. Copeland, Public Relations Officer of the Association sponsoring the film.

Ant Warfare (8 minutes) records an experiment by Dr. Wragg Morley. A bridge was provided between the territories of two ant colonies, one of which had no food while the other had a good supply. The film shows the invasion of the latter territory and its conquest.

Tickets of admission are not required and Fellows are entitled to introduce two guests. Light refreshments will be served in the Library afterwards at a charge of one shilling a head.

SOME MYSTERIES OF METALS

A Dr. Mann Juvenile Lecture by

PROFESSOR E. N. da C. ANDRADE, D.Sc., Ph.D., LL.D., F.R.S.

Wednesday, 5th January, 1955

When I received the pleasant invitation to deliver a Dr. Thomas Mann lecture I had naturally to consider what I should choose as my subject. It had to be something that would interest you and I thought that it would be easier if it were something that interested me too. Atomic power, space travel and television occurred to me as possible subjects, but it seemed that to-day many of you are made familiar with the simpler side of these matters at school and in popular books and the popular press. The ordinary mechanical properties of metals—their strength, their endurance, their softness, their hardness, their springiness, for instance—are, on the other hand, matters which, although they are very important, are very seldom talked about in a simple way. I have, in my scientific work, spent a good deal of time looking into certain properties of simple metals and I have found it an exciting subject. So I thought that I would try to interest you in it.

In particular, I think it is well for people to realize that the problems of the atomic nucleus, fascinating as they are, are not the only region of physical

The Lecturer with some of the audience

science where discoveries, important discoveries, are still to be made. The mechanical properties of metals have been studied throughout historic time and they daily increase in importance: in fact, far more metal has been taken out of the earth during the past fifty years than in the whole previous ages of mankind. It is, however, true to say that we still know remarkably little about why they behave as they do. It may surprise some of you to learn that at Harwell, that great centre of research into atomic power, there is a large and important section engaged in investigating the properties of both solid and liquid metals.

Matter, as you know, can exist in three forms, solid, liquid or gas, which in a familiar case are ice, water and steam. From the scientific point of view gases, although in most cases we cannot see them, are the simplest. When we are considering mechanical properties, that is, the behaviour under pushes, pulls, sliding motions, pressures, and so on, solids are much worse than liquids. I have here a bottle of a clear liquid, called diethyl acetonedicarboxylate, and an ordinary steel rod, and I suppose that you would consider the rod likely to be the simpler. In certain ways, however, it is much the more complicated. If I tell an organic chemist the formula of the liquid he can—with his books around him—tell me all about its properties. If I tell the best metal man in the world the exact composition of the steel rod—pure iron with such and such small percentages of carbon, manganese, silicon, and so on—he cannot tell me its breaking strength, how much it will stretch before breaking, or any of its mechanical properties. He will want to know first the history of the steel, how it has been heated and cooled, hammered, rolled or what not. The reason for the difference is that metals have a structure and, for one and the same metal, this structure may be very different, according to the treatment that the metal has received. The chief point of this talk is, in fact, that everything depends upon structure.

If I may take a rough illustration, suppose that you have a bottle of ginger ale made by the well-known firm of Higgs and Biggs: you know just what you are getting. But suppose that you have a cake made with standard flour, butter, fruit and other ingredients: it may have almost any properties, from stony hardness to unpleasant doughiness, according to how it has been cooked. Metals are more like cakes than ginger ale.

Let us have a word about the structure of metals. All metals are made up of masses of little crystals, and crystals are structures in which the atoms of which they are composed are arranged in a regular pattern. (*A slide was shown to illustrate this.*) The individual little crystals are often called crystal grains and in the metal they are separated by crystal boundaries. The grains may be very small, less than a thousandth of an inch across, or they may be a tenth of an inch across or much larger. If molten bismuth is poured out of a crucible large crystalline masses are left behind. By suitably treating a metal, some of the crystal grains may be made to grow at the expense of others. Figure 1 shows aluminium specimens that have been subjected to different strains and heating treatment so as to produce crystals of different sizes. (*Slides were shown to illustrate the variation of crystal grains in size and appearance in different typical metals and*

alloys. Something was also said about the methods of rendering crystal structures visible.) By special methods pieces of metal can be prepared in which the whole is one crystal—single crystal specimens, they are called. (*A large single crystal sphere of copper was shown.*)

Let us now look at a few simple but remarkable examples of metal behaviour. I bend a soft iron rod as much as I can: my assistant here [a strong young member of the audience] cannot bend it back, and it is particularly resistant where it has been most bent. (*The same was shown with a soft copper rod.*) Here is a copper rod which has been so prepared that one end is soft, while the rest is hard. (*Ease of bending one end and difficulty of bending other demonstrated.*)

This change on bending is particularly marked with single crystal specimens. (*A rod of copper about 3 mm. in diameter and 6 cm. long, which had been converted into a single crystal, was firmly clamped at one end so that it projected horizontally. A load of 100 grams at the free end produced very large bending. The clamped end*

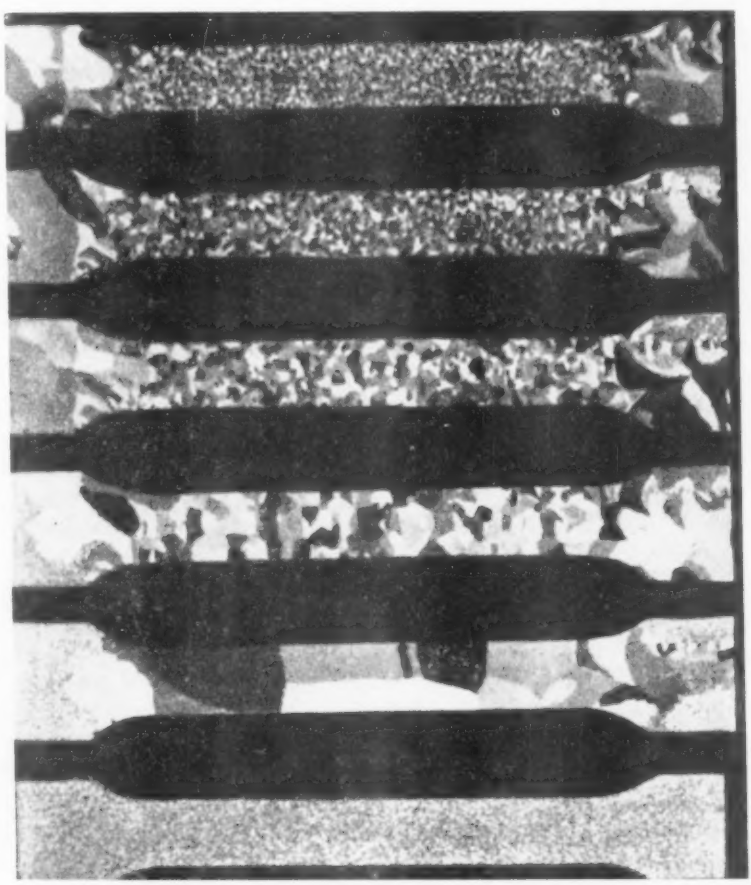


FIGURE 1. *Specimens from the same sheet of aluminium that have been variously treated so as to produce crystal grains of different sizes*

was then rotated about its axis so that the belt part stuck up and it was shown that 200 grams were needed to produce partial restoration. This kind of process was repeated, and after a few bends backwards and forwards the rod would support a weight of 1,000 grams without bending.)

Let us try the same kind of thing with stretching instead of bending. (*A soft copper wire was shown to become quite hard and unstretchable when pulled out: it broke sharply when the load reached a certain value. A cadmium wire in single crystal form was shown to stretch visibly under a very small load and to continue stretching as the load was increased until it was over three times its original length, and could support a much larger load.*)

This property of growing more resistant under bending or stretching is what is called 'work-hardening'. It is one of the mysteries of metals. It is accompanied by changes in the crystal structure which are particularly easy to see in single crystal specimens. The single crystal wire, when pulled out, becomes not a thinner cylinder but a flattened strip, as thick as the original wire in the broad direction of the strip, but only a third or so as thick in the narrow direction, with our particular specimen. The appearance is as if the crystal had stretched by slices of it slipping over one another, as in a pack of cards spread out. (*A series of slides were shown to illustrate this, of which Figure 2 (a) is representative.*) Slipping on glide planes in this way is one of the methods in which crystal grains in a metal can change their form. The slipping stops, of course, at the crystal boundary: this is one of the reasons why ordinary polycrystalline metals resist deformation better than single crystals do.

Soft iron wires when bent make sharp angles, instead of smooth curves, as copper wires do. This is because they become softer, not harder, when they begin to yield, at the so-called 'yield point', another mystery on which much work has recently been done. (*The yield point was shown by bending.*) The yield point is caused by small amounts of certain other stuff in the iron.

We have looked quickly at some effects of handling; let us look at some effects of heat. (*One end of a steel spring was made soft by heating and leaving to cool, the other end brittle by heating and quenching in water. The soft end was permanently bent; the brittle end snapped off in the hand. A hard copper wire was softened by heating.*)

A general effect of heat is that metals are softer at high temperatures. Metal tubes and rods are made by using very high pressure to squeeze the hot metal out through dies of suitable shape, the method being the same as that by which macaroni and spaghetti are made. (*Slides were shown of the process.*) Metals are often prepared by heating a metal powder until it is soft and then squeezing it so that it sticks together in a solid mass, the process known as sintering. It is used for preparing masses of metals of very high melting point, such as tungsten, or for making porous metals for bearings, which let the lubricating oil through the metal. (*A tungsten finger ring was shown.*)

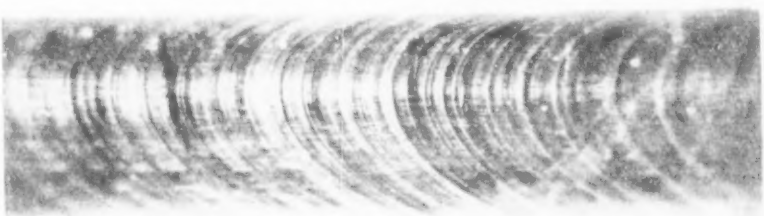
Metals, however, do not get softer and softer indefinitely, as glass does, when heated but, instead, suddenly turn from solid to liquid when a certain temperature is reached—they have a sharp melting point. This is characteristic

of a crystalline substance. (*An experiment was shown to illustrate the difference in behaviour of a lead rod and of a glass rod when the temperature was raised.*)

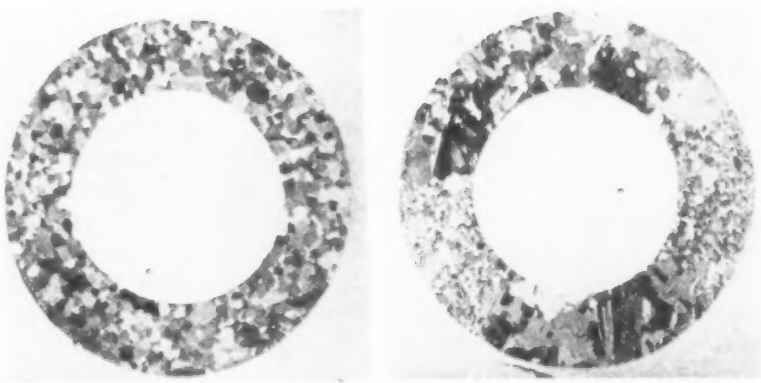
I want to refer briefly to two properties of metals that have had great practical importance recently: creep and fatigue.

If a metal, especially when the temperature is not so far from the melting point, is kept under a heavy load it will very slowly flow. This is called creep. It is a serious trouble in turbo-jet engines, for instance, since the turbine blades are very hot and if, as time goes on, they continue to lengthen appreciably under the centrifugal force they will foul the wall that encloses them. To make alloys that resist creep at high temperature is an important undertaking nowadays. Creep has many less sensational points of interest.

If a metal is bent backwards and forwards repeatedly by a force less than that which it can stand if steadily applied, in the end it seems to get tired of being messed about and may break, a process called fatigue. Of course, the vibrations in aircraft lead to such backward and forward movement in certain



(a)



(b) (c)

FIGURE 2. (*a*) *Single crystal of cadmium, which has been stretched, magnified 20 times:* (*b*) *cross-section of a good lead pipe:* (*c*) *cross-section of a bad lead pipe*

parts of the structure and to-day fracture under fatigue is a process that has to be very carefully studied. In fatigue testing machines the specimen often undergoes many millions of very rapid changes of stress (about 50 per second) before it breaks, but if the stress is less than a certain amount the specimen will, apparently, last for ever. (*A specimen which had undergone 3 million cycles in a test machine was broken with a single hammer blow, in consequence of a fatigue crack that had formed.*)

Most metals in use nowadays are alloys, made up of two or more metals, and alloys have most complicated properties. The properties are not the average properties of the metals in the alloys: for instance, bismuth, lead, tin and cadmium all melt at temperatures well above 200°C., but an alloy of these four metals melts at 60° C. Both iron and nickel expand with rise of temperature, but a certain iron-nickel alloy does not. Once more, it is all a question of structure.

We will look at one or two queer alloy properties. (*Strips of a certain zinc base alloy were shown to bend under slowly applied stress, but to snap if rapidly bent. Brass was shown to snap if sponged with a solution of a mercuric salt. A rod of cadmium containing a small trace of bismuth, under bending stress, was shown to snap when boiling water was poured on it.*)

Magnetism gives good examples of strange alloy effects. (*An alloy of copper, aluminium and manganese was shown to be strongly attracted by a magnet, although the three metals are non-magnetic. A wire of a special steel was shown to be non-magnetic as taken off the reel, but to become magnetic on being stretched to breaking point. A very strong magnet of alnico was shown, the metal being only about half iron, with large additions of aluminium, nickel and cobalt.*)

We have now looked at a few examples of the mysterious behaviour of metals. A great deal of detail is not yet fully understood, but the general explanation is to be found in the crystalline structure. Whenever the properties change there is a change in crystal structure which can be recorded by the microscope and by X-rays, suitably applied. Sometimes the microscope is scarcely needed, as in the example of good and bad lead pipe shown in Figure 2 (*b*) and (*c*).

One feature of metal crystals which is of the greatest importance for understanding their mechanical properties is that they are never perfect throughout. Each crystal plane in a simple perfect crystal is like every other parallel crystal plane and the atoms fit into the pattern in the same way at every point. In real metal crystals there are, here and there, places of misfit, called dislocations. These places of misfit run easily along the plane and lead to the kind of big movement on glide planes which we have seen to take place (Figure 2 (*a*)). The nature and movement of dislocation can be illustrated by a model. (*The model, made of wooden cylinders, was shown. In Figure 3, (a) shows the two rows of regularly spaced rollers, those of the upper row being connected by an elastic strip. These rows represent a perfect crystal. In (b) a dislocation, marked by the white line, has been created in the upper row. This can be made to run to the left, as shown in (a) and (d), by quite a small force, and finally, in (e), the whole top row has been moved by one spacing, as compared with (a). To move the whole top row, in (a), at once would have needed a very large force.*)

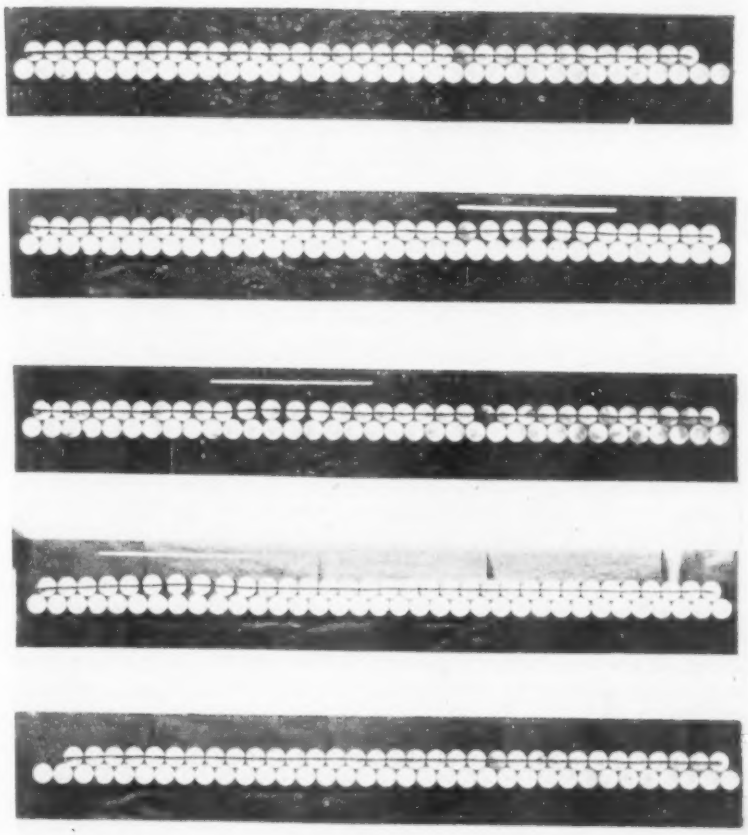


FIGURE 3. *Roller model, to illustrate the passage of a dislocation*

The easy passage of dislocation within crystal grains, and their stoppage at crystal boundaries, can be made to account for some of the mysteries of pure metals. Odd atoms, which can block dislocations, combinations of different metals to form strange crystals, crystal growth, crystal changes, crystal distortion, all go to make the machinery of metals difficult to understand in its details. But what is simple, and what I hope you will all be able to understand and remember, is that the mysterious behaviour of metals is all a matter of structure and that in that structure faults of fitting play a very important part.

I am very grateful for help for this lecture received from Mr. G. L. Bailey and Dr. J. McKeown, of the British Non-Ferrous Metals Research Association (specimens and slides); Dr. C. Sykes (magnetic and non-magnetic steels); Dr. J. W. Jenkin (slides and specimens); Dr. N. P. Allen (special zinc base alloy); Professor L. F. Bates (Heusler alloy), and Dr. Ronald King (copper and cadmium specimens).

THE COPPERBELT OF NORTHERN RHODESIA

The Henry Morley Lecture by

R. L. PRAIN, O.B.E.,

Chairman of the Rhodesian Selection Trust Group of Companies, delivered to the Commonwealth Section of the Society on Thursday, 6th January, 1955, with Sir Gilbert Rennie, G.B.E., K.C.M.G., M.C., High Commissioner for the Federation of Rhodesia and Nyasaland, in the Chair

THE CHAIRMAN: This evening we are going to have the pleasure of hearing Mr. R. L. Prain deliver the Henry Morley lecture. This trust lecture was endowed from a bequest made to the Royal Society of Arts by the late Henry Morley, who was a Life Fellow of the Society, and Secretary of the Niger Company. The Henry Morley lecture is an annual event and was first delivered in 1949.

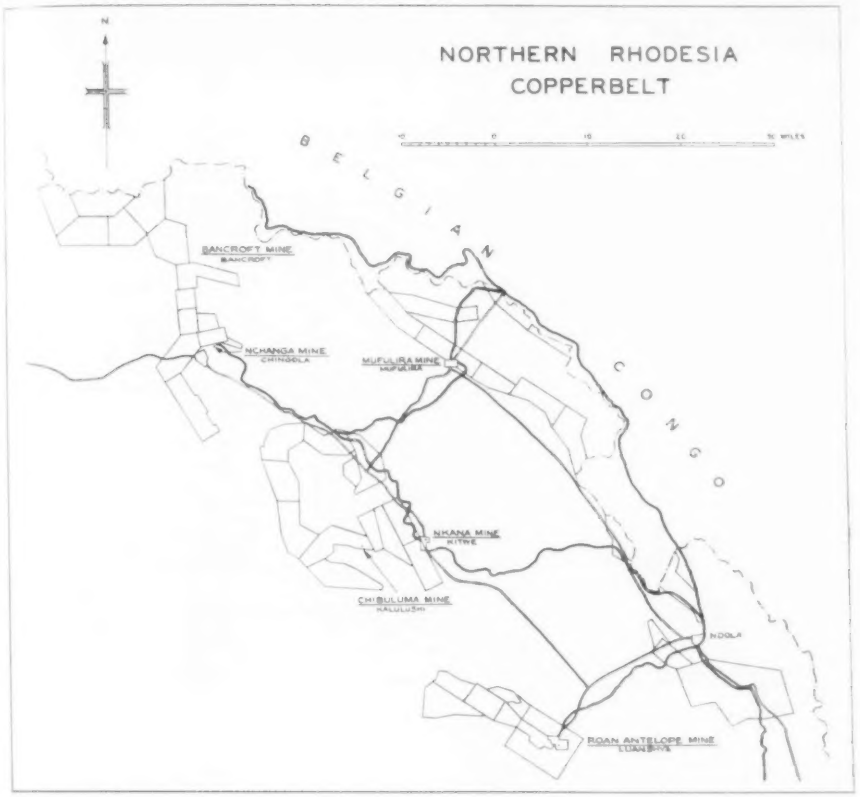
Mr. Prain, I think you will agree, needs no introduction by me. To-day he is going to talk to us on a subject in which he is very well experienced and which he knows very well indeed. He has been connected with the copper-mining industry for, I think, twenty-nine years, and with the Copperbelt of Northern Rhodesia, which is to form the subject of his address, for over seventeen years. He knows as much as anyone and more than most about the problems of the Copperbelt—problems that are attracting a great deal of attention at the present time—and I think we are very fortunate in having the benefit of Mr. Prain's address to us this evening.

The following lecture was then delivered:

THE LECTURE

I should like to begin by thanking the Chairman of your Commonwealth Committee for the invitation to address you to-day on the subject of the Copperbelt of Northern Rhodesia, and to add how much I appreciate the honour of having this address designated as the Henry Morley Lecture for 1955.

We must begin by defining what we mean by the Copperbelt. This term is generally used to denote that region of Northern Rhodesia in which are situated the copper mines of that territory. The first published use of the term Copperbelt which we have been able to trace dates back to 1905. The *African World* of December of that year contained an article entitled 'The Great Northern Copper Belts of Rhodesia', by a Major F. E. Ricarde-Seaver who was, incidentally, the originator of the Victoria Falls–Rand transmission scheme. He used the term in the plural to include the present Copperbelt and the one on the Kafue in the Mumbwa District. The next reference we have traced is in 1909 in an article in the *Transactions* of the Geological Society of South Africa. It began to be used quite generally in the late 'twenties, and by 1929 it was in common



use to denote the region which to-day comprises the existing copper mines of Northern Rhodesia. You will see from what I have said that at one time it included the small deposits in the Mumbwa area, with picturesque names such as Sable Antelope, Silver King and Hippo, which never came to anything, but it has long ceased to denote that particular area.

Within the present Copperbelt there are four great producing mines, two developing mines, and one township called Ndola, which is not a mining town but is a railhead on the main line, and which has developed primarily as a result of the mining industry in the neighbourhood. It describes itself as the Gateway to the Copperbelt and it is shortly to become a refining centre.

If we take this area and lay it on a map of England of the same scale and we place the centre of the Copperbelt approximately over London, it would cover the same area as that bounded by the towns of Buckingham, Chelmsford, Canterbury and Tunbridge Wells.

The region as a whole lies within the administrative district of the Western Province of Northern Rhodesia and that, in turn, lies immediately to the south of the Rhodesia-Congo Border. There is considerable prospecting being done outside the present Copperbelt and, should new mines be discovered within the

prospecting areas, I personally have little doubt that the definition of the Copperbelt will be extended to cover such new mines as well. In other words, the expression 'Copperbelt' is at present a loose one and may well, as time goes on, become an expanding one.

The boundary between Northern Rhodesia and the Belgian Congo at this point was only ill-defined before the late 1920s. On the other side of the border lie the great copper mines of the Katanga Province of the Belgian Congo. The opening up of the Rhodesian Copperbelt made it essential that this border should be defined exactly, especially as one of the Belgian mines, the Kipushi Mine, lies actually on the border. As a result of this necessity an Anglo-Belgian Mission completed an exact delimitation of the border in 1932. This mission was led by Lieutenant-Colonel E. R. L. Peake, M.C., of the Royal Engineers and by the Belgian Colonel Gendarme. The border which they established at this point follows the watershed between the Zambezi and the Congo Rivers.

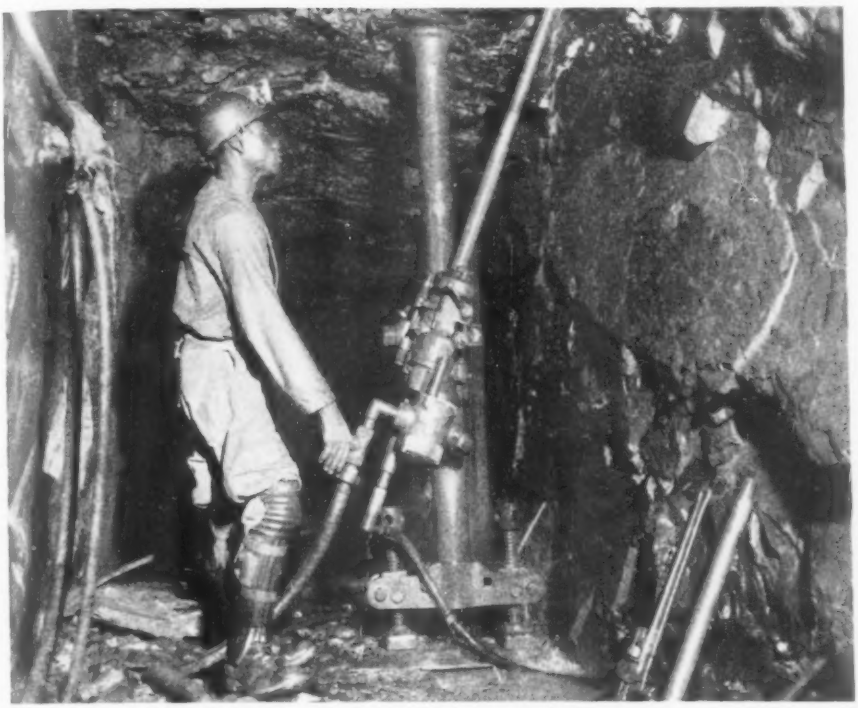
Within the Copperbelt of Northern Rhodesia exists to-day the second largest copper-producing industry in the world. From its mines there now comes a copper production with an annual export value of £100 million, when copper is at a price of approximately £250 per ton. All of this is available in sterling to the United Kingdom and to the Commonwealth and, to that extent, it constitutes one of the largest dollar-saving commodities produced within the Empire. Its production, in fact, is larger than the requirements of new copper of the United Kingdom and therefore considerable quantities are exported to the United States and bring in actual dollars.

The capital invested in the mines themselves, to say nothing of the surrounding government townships and secondary industries, is of a historical value of about £100 million, which I calculate at to-day's value of the pound would be £154 million.

Within this industry there are employed approximately 6,000 Europeans and 35,000 Africans who, with their families, constitute a population of at least 125,000 people on the properties of the mines. If we take into account the other people living in the Copperbelt who find employment as an indirect result of the copper mines, including all government officials and servants, and all personal servants, and those working on the railways, in the stores and industries, we find that there are probably a quarter of a million people living on the Copperbelt and owing their existence there in one way or another to the copper-mining industry.

This industry in 1953 produced about 93 per cent of the export revenue of Northern Rhodesia and accounted for about 80 per cent of the tax revenue of the country, quite apart from the personal taxes which may be paid by the employees of the companies. If we express these statistics in terms of the Federal revenues, that is to say the revenues of the Federation of both Rhodesias and Nyasaland, we arrive at figures which show that copper accounted for over 60 per cent of the exports of the Federation and over 50 per cent of the taxes.

Finally, to give you an idea by means of statistics of the scope of this industry, I would guess that at present the profits of the industry are running at about £40 million a year before taxes.

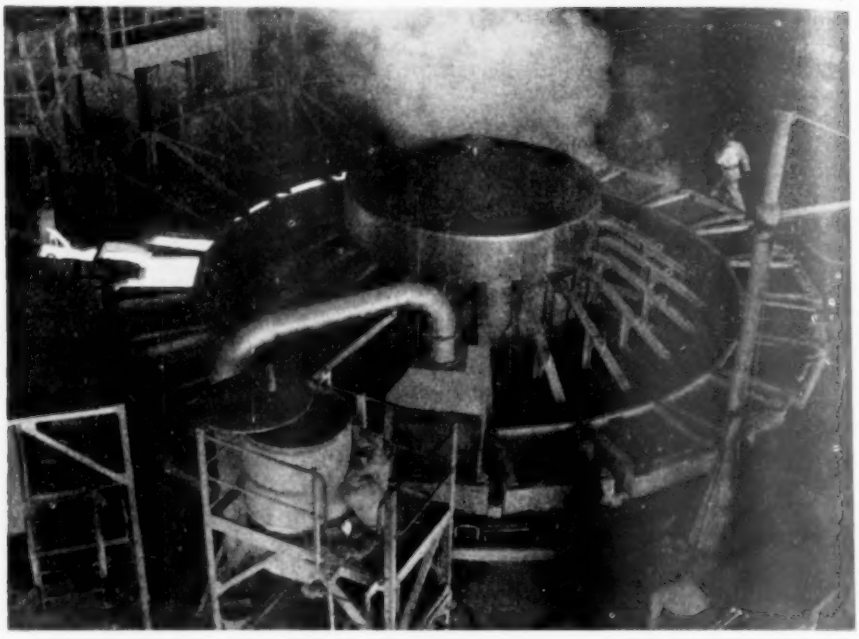


Blast hole diamond drilling, Roan Antelope Mine

I apologize for submitting this volume of statistics to you so early in this address, but I do so deliberately to give you at the outset some impression of the size of the industry which I am about to describe.

I believe it is one of the largest integrated industries south of the Equator and it is to-day the most valuable extractive industry in the British Colonial Empire, and second only to rubber among all industries in the Colonial Empire, if it is valued by reference to its export value. The amount of development taking place in Northern Rhodesia, chiefly in the Copperbelt, in terms of gross capital formation (to use a statistician's term) is, according to the available evidence, at present greater per head of population than in any other British Colonial territory in Africa.

The commercial and strategic importance of the Copperbelt is matched only by the complexity of the problems which this industry has to face, problems which arise partly from its remote location and partly from the inevitable and sudden impact of a highly complex modern industry set down among some of the most primitive people in the world, from which such a large proportion of its employees has to be drawn. This situation obviously brings with it social problems on a scale which it is difficult to match elsewhere, and which I shall later describe.



Casting wheel, Mufulira Mine

The history of this industry is of comparatively recent origin. Copper had been worked for centuries in Central Africa by the native peoples on a most primitive scale and this started a certain amount of prospecting in Central Africa after this part of the world attracted public attention as a result of the travels of David Livingstone. The first prospecting by Europeans appears to have occurred towards the end of the last century and it was in 1899 that George Grey discovered the Kansanshi Mine and in 1902 that the outcrop of the Roan Antelope Mine was discovered by a prospector named William Collier who also in that year found the Bwana Mkubwa Mine.

Even these discoveries, however, attracted little attention at the time owing to certain factors which at that time were considered to be unfavourable for the opening up of copper mines in this part of the world. There were at least four major factors. To begin with, the enormous distances and transportation problems involved, and secondly the health problems, among which the scourge of malaria appeared to be insuperable. Thirdly, at that time the United Kingdom had the whole world to buy copper from and had not yet experienced the dangers of a world war, nor the embarrassment of a dollar shortage. The fourth problem concerned the technical difficulties of treating the particular types of ores represented in the Kansanshi and Bwana Mkubwa Mines.

Most of these problems, however, disappeared during the following twenty-five years. The railroad was extended from the Victoria Falls to the Belgian

Congo to serve, first, the Broken Hill lead and zinc mines and, secondly, the Katanga copper mines. The pioneer work of Ross and Watson in the Malay Peninsula showed how malaria could be controlled. The growth of metallurgical and geological experience during the first quarter of the century also completely altered the outlook towards the Rhodesian occurrences. In the Katanga, oxide ores averaging as much as 15 per cent copper were common but the search for similar deposits on the Rhodesian side resulted in the finding of ores of much lower grade, with an average of perhaps 3 per cent to 5 per cent copper, also in the form of oxides. Pitting and shaft sinking down to water level gave discouraging results. What was not realized until later was that, at moderate depths but generally well below ground water level, these same lean Rhodesian oxide copper deposits turned to sulphides still running from 3 per cent to 5 per cent copper. This realization occurred at about the time that metallurgical science was discovering the so-called flotation method of concentration, which enables sulphide ores of such grade to be profitably exploited. This combination of new geological and metallurgical knowledge created immense interest in the Rhodesian deposits, which thus assumed relatively suddenly an economic value which had never previously been attributed to them.

During this quarter century, furthermore, the United Kingdom had learned the lessons of a world war and was determined, if possible, to acquire Empire sources of copper for the future.

The combination of all these various factors led to renewal of interest in this part of the world and it was in the 1920s that exploration on a really considerable scale began. Tribute should be paid at this point to what is perhaps the most important single step which led to the opening up of the Copperbelt, and that was the decision in 1923 by The British South Africa Company, who owned and still owns the mineral rights of Northern Rhodesia, to grant sole prospecting rights over large areas of the territory to strong financial companies. The 1920s were essentially the years of the concession companies such as the Rhodesian Congo Border Concession Ltd. and the Nkana Concession, and it was during that time that there were discovered the mines of Mufulira and Nchanga.

The Nkana Mine was discovered in 1910 by Mr. Moffat Thompson. Both the Kansanshi and the Bwana Mkubwa Mines, which I have already mentioned, produced copper before the First World War. The Kansanshi Mine suspended operations on the outbreak of the war, while the Bwana Mkubwa Mine, which started operations in January, 1913, suspended operations in September, 1914. It resumed operations in 1916 and continued until the end of March, 1918. During those two periods of activity the mill treated about 69,000 tons of ore, assaying about 10 per cent copper. The concentrates were sent partly to the Falcon Smelter in Southern Rhodesia and during the war a certain tonnage was shipped to England. This mine again produced some quantities in the late 1920s but shut down finally in about 1930. These productions, however, were in a way experimental and of no importance in the world's copper picture. The important era of Rhodesian copper production began with the decision to develop the four orebodies of Roan Antelope, Nkana, Mufulira and Nchanga.

The result was immense financial activity, mostly in the City of London but also in New York and Johannesburg, and the formation of large companies to operate these mines. Production on a large scale first began in 1931 and has continued unbroken on an increasing scale since then.

In my opinion the next major development for the Copperbelt was in 1949 with the devaluation of sterling and the consequent increase in the price of copper. This led to a further interest in the copper mines and, coupled with an enlightened tax code which was introduced in 1951, it led to the beginning of two other mines which I shall describe in due course.

Organizationally, the copper mines of the Copperbelt fall into two groups, one predominantly controlled by British and American interests and the other predominantly by South African interests. These two groups between them control all the companies concerned directly with copper mining on the Copperbelt and which, as I said before, include four producing mines, two developing mines and, in addition, more than a dozen subsidiary companies which serve the main mines. I should like to give you now a brief résumé of each of these mines and, of course, I can only give you such information as you can find for yourselves from the Reports of these companies. I will deal with them in the order in which they came into production.

Roan Antelope, which I have already mentioned as being discovered in 1902, was formed into a company in 1927 and started production in 1931. This mine is situated next to a town called Luanshya, which you will see on the accompanying map down towards the south-west corner of the Copperbelt. This mine is to-day hoisting and milling between 5 million and 6 million tons of ore each year and on this basis can claim to be the largest underground copper mine in the British Empire. It is large by any standard, having a peculiar shape to its orebody, the strike of which extends for about 10 miles on the surface. To work this orebody 24 shafts have been sunk from the surface and no less than 900 miles of underground workings have been driven. The ore is crushed, floated and then smelted to produce a blister copper which is shipped to the markets of the world, and the actual copper production of this mine runs between 85,000 and 90,000 tons a year, with a value of about £22 million at £250 a ton. The number of European employees at Roan is about 1,560 and African employees 9,800. These African employees live in an African township which covers over a thousand acres which, I believe, makes it the biggest African mine township on the subcontinent.

Thirty-six miles by road to the north of Roan Antelope there is the mine of Nkana which, as I mentioned earlier, was discovered in 1910. The company which owns and operates this mine is the Rhokana Corporation, which is the successor of the Rhodesian Congo Border Concession Ltd., which was formed in 1923. There are actually two mines worked jointly, Nkana and Mindola. They began production in 1931 and to-day produce about 85,000 tons of copper a year.

In addition to being a mining centre Nkana is a concentration of smelting and refining facilities. When the extensions to the present smelter are completed

this will be the second largest in the world. Some of the plants at Nkana are treating copper from other mines. The number of European employees at Nkana is over 1,750 and African employees about 10,800.

Nkana is also about the geographical centre of the Copperbelt. For this reason the adjoining township of Kitwe has attracted to itself a considerable amount of centralized business activities, in addition to secondary industries and stores which are established there. It contains the headquarters of the Chamber of Mines and the various mining unions, as a result of which Nkana and Kitwe together form the biggest population centre on the Copperbelt. This dual town is growing at a phenomenal rate; it expects to treble its size within five years and it will easily be the largest town in Northern Rhodesia, even if it is not already so.

Twenty-six miles to the north-east of Kitwe is the Mufulira Mine, which was discovered in 1923 and began production in 1933. This is one of the large copper mines of the world, both in the size of its mining operations and of its ore reserves. It is also one of the wettest mines, the amount of water which is pumped out of it daily being about ten times the amount of copper ore. Mufulira is capable of producing 90,000 tons of copper a year.

Thirty-two miles north of Kitwe is the great Nchanga Mine, discovered in 1923 and which came into production in 1939. The grade of ore at Nchanga is higher than that at the other mines I have mentioned and, although it does not mine and mill the highest tonnage of ore, the result in terms of copper is the highest on the Copperbelt, running to-day at over 110,000 tons per annum. This mine also has huge reserves and it has recently been announced by the Nchanga Company that they will start an open pit operation in the near future which will even out the grade variations in the various parts of the mine.

I mentioned earlier two new developing mines. The first of these, which is expected to come into production in 1955, is the Chibuluma Mine, situated about six miles to the west of Kitwe. This is a relatively small but high-grade copper/cobalt mine which is expected to produce about 20,000 tons of copper a year. It is of interest to note that of all the mines or deposits mentioned in this address, Chibuluma, which was discovered in 1939, alone has no surface expression, and to this extent may be regarded as a triumph of systematic prospecting. The other developing mine is the Bancroft Mine, which is about 15 miles north of Nchanga and therefore very near the Congo Border. The Bancroft Company was formed recently to acquire and work the two orebodies known as Kirila Bomwe and Konkola. This mine is expected to come into production in 1957 and has announced that it will produce about 48,000 tons of copper each year.

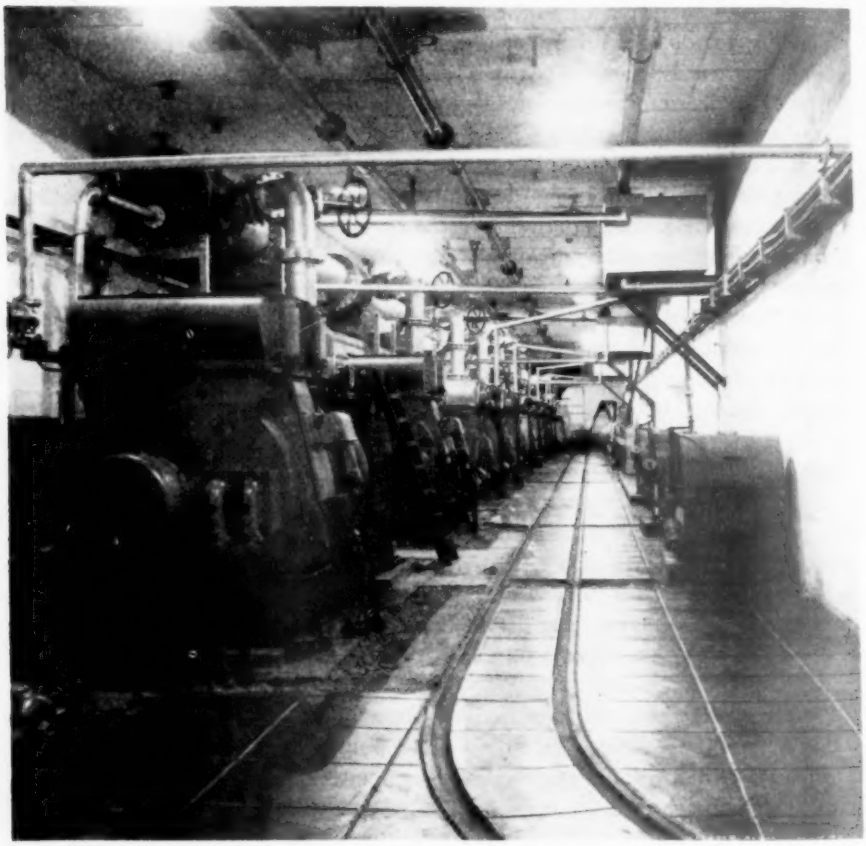
In addition to these two new mines there are several other known orebodies which are not yet being developed but which publish ore reserves. These include the Baluba Mine, with ore reserves of 70 million tons, and the Chambishi Mine, with published ore reserves of 25 million tons.

If we add up the ore reserves of the existing mines, the developing mines and the undeveloped mines, we find reserves of a minimum of 700 million tons,

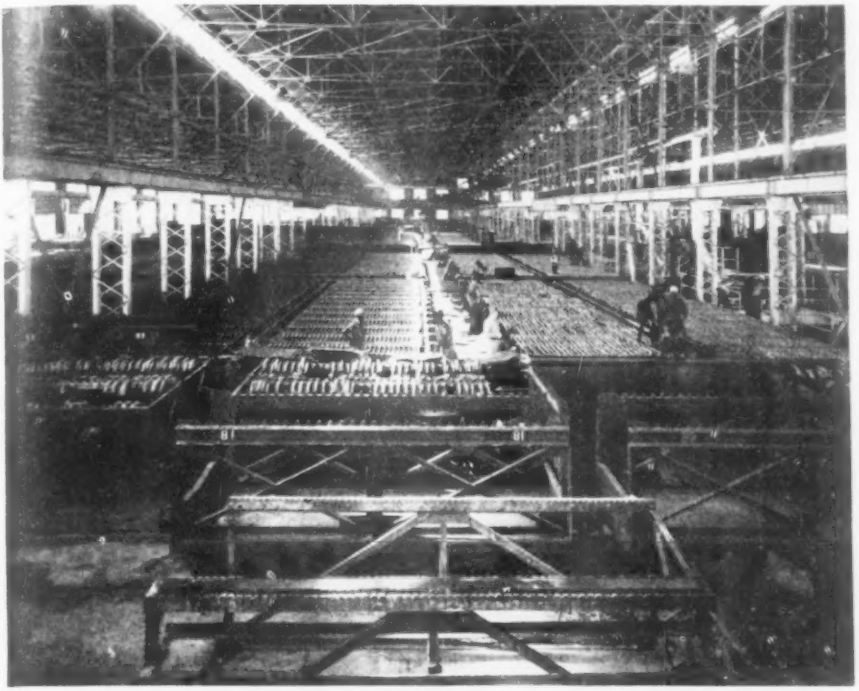
capable of yielding at least 15 million tons of copper. This represents about 20 to 25 per cent of the world's known reserves in terms of recoverable copper.

Some of these mines produce, or will produce, metals other than copper. For many years the Rhokana Corporation has been producing cobalt and at present its rate of production runs at about 2,400,000 lb. per annum, which represents about 12 per cent of the world production. Chibuluma will also produce cobalt at a rate which has been announced at 500,000 lb. per annum, and cobalt is known to exist in, for instance, the Baluba Mine. All these mines produce small quantities of gold and silver as a by-product of electrolytic refining but they are not important producers of these metals in any sense. Rhokana recently announced that it will produce some uranium.

Among copper producing countries the United States comes first with an annual production of about 825,000 tons. For many years Chile took second place with a production which averaged about 383,000 tons a year over the last twenty years.



Underground pump station, Nchanga



Tank house, Nkana

In 1953, however, for the first time Rhodesia came into second place and it is likely that it will hold this place for many years to come. If, as I mentioned earlier in this address, the Katanga is taken as the same geological field as the Rhodesian field, this district would to-day be very easily the second and one day perhaps the first copper producing field of the world.

I mentioned earlier that there are a dozen or more subsidiary companies which exist to render services to the producing companies. Of these perhaps the most important are those which deal with the provision of power supplies and the provision of refining facilities. The Rhodesia Congo Border Power Corporation exists for the purpose of purchasing the power produced at the four thermal power stations at the mines and of redistributing this power throughout the Copperbelt. In addition, it will import power beginning in 1957 from a hydro-electric scheme established on the Lualaba River in the Belgian Congo under agreements entered into between the companies and the Union Miniere du Haut Katanga. If at a later date, probably 1961, power becomes available as is expected from a hydro-electric scheme in the Rhodesias, either on the Kafue River or the Zambezi River, this Corporation will also import power from that source and redistribute it within the Copperbelt. If and when this occurs the total system which will be controlled by the Rhodesia Congo Border Power Corporation will extend from the Lualaba River in the north to

the Kafue or the Zambezi River in the south, a total distance of nearly 800 miles, which will, I understand, make this the longest integrated power system in the world. When that happens the central switching station of this system, which is situated near Kitwe, will cover twenty acres, which I believe is bigger than any switching station in the United Kingdom.

The refining of copper is in the hands of three refineries. One of these belongs to the Mufulira Company and exists for the purpose of treating merely the Mufulira output. The other two are respectively owned by the Rhodesia Copper Refineries Limited and the Ndola Copper Refineries Limited, both of which exist to treat the output of more than one mine.

The subsidiary companies include the Northern Rhodesia Chamber of Mines, which constitutes the employers' organization, and also other companies dealing with the provision of air services, timber, supply of labour, supply of technical services, an estate company, trustee companies and prospecting companies.

Of the latter there are four companies in being at present which between them cover prospecting concessions of about 35,000 square miles in area. To

Coarse ore storage bin, Nchanga

give you an analogy with the United Kingdom, this is an area equivalent to that of a circle superimposed on a map of England of the same scale, with its centre at Rugby and on whose circumference would be found the towns of Liverpool, Hull, Southampton, Bristol and Cardiff. Over this area prospecting is now taking place on a scale comparable with that which occurred in the 1920s. The prospecting is being conducted on a scale which employs all the modern techniques of prospecting, including geophysics, geochemistry and aerial photography. It is too early yet to say whether these prospecting campaigns will discover new mines of the size of the existing ones. It would be surprising if no comparable results were obtained as the areas cover the same geological series as constitutes the Copperbelt.

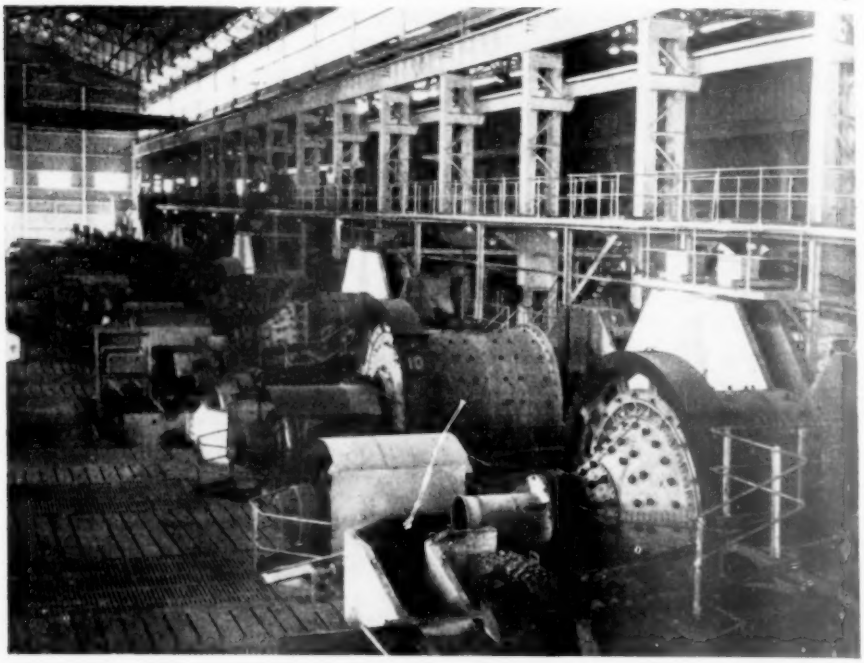
The figures which I quoted earlier as to the relative importance of the copper industry within Northern Rhodesia and within the Federation illustrate the obvious fact that, at any rate as far as Northern Rhodesia is concerned, the copper industry constitutes virtually a mono-economy. Even taken within the context of the Federation the copper industry is overwhelmingly the biggest industry within the Federation. It may be compared to the mono-economy of Chile with its similar copper industry, or with the analogies to be found in the oil industry in the mono-economies of Persia and Venezuela.

The earlier hazards of malaria and other tropical diseases are now largely a matter of historical record. With the modern methods of eliminating these hazards, the Copperbelt, as in fact the whole of the Rhodesias, finds itself situated in a climate which compares well with anywhere else in the world. The companies have created amenities and facilities for both their European and African employees which it would be hard to equal in the mining industry. Africans who only a few years ago were living in primitive conditions in the 'bush' now live in houses which are being equipped with water-borne sewerage and electric light, and enjoy medical facilities which bear favourable comparison with those available to the majority of people in the British Isles. Their diet contains a calorific value in excess of that available here during the last war and probably in excess of that available to-day to nine-tenths of the world's population.

The scale of pay and remuneration for both European and African employees is comparable to that found anywhere else in Africa. In saying this I refer, of course, to two different scales of pay and remuneration, namely, one scale for the European, which compares favourably with that of Europeans anywhere else in the mining industry in Africa, and the other for Africans, which compares more than favourably with that for Africans anywhere else within the Federation.

I now turn to the two major problems which confront this industry and to which I referred earlier, namely, the problem of providing sufficient power for this industry and the social problems created by the existence of two civilizations living and working side by side.

So far as power is concerned, this is a complex problem involving three factors: the supply of fuel, the provision of transport to carry that fuel from its source to the mines, and the question of generating capacity to provide electric power. The natural fuel for these mines is coal supplied by the Wankie Colliery



Ball mills, Mufulira Mine

in Southern Rhodesia. The Wankie Colliery has always been a key factor in enabling this industry to start up in the first place and to carry on in the second. There is no other major source of coal within the Federation and for many years no real problem existed as the capacity of the Wankie Colliery, which is one of the great collieries of the world, to supply coal to the Copperbelt was not in any doubt. With the great expansion of this industry which has occurred in recent years, and with the great expansion of European population and of secondary industries which has occurred throughout the Federation, the Wankie Colliery has been hard put to it since the war to supply enough coal for the copper industry, the railroads, and the other requirements of the Federation. This particular aspect of the problem is now solved, for the colliery can now produce coal in excess of the requirements of the Federation. The problem to-day is principally one of transporting this coal from the colliery to the various users within the Federation. The Rhodesia Railways system has been found unable to carry the full requirements of the Federation and, as a result, until the Rhodesia Railways system can be brought up to its contemplated carrying capacity, the consumers of the Federation are being rationed. In this way the Copperbelt, with a requirement of 90,000 tons of coal per month, is at present unable to receive more than about 70,000 tons, and the difference has been made up for some years now by resorting to the expediency of burning wood. Fortunately, there is no shortage of the latter and since 1946 the copper mining companies

have conducted a large-scale campaign of cutting wood in the local forests and transporting it to the power plants of the Copperbelt. This has created a large secondary industry, which at present employs about 7,000 Africans and has so far cleared about 200 square miles of the local forest. The wood is brought in by lorries and to-day it is bringing in fuel from up to twenty miles from each of the mines. This is an expensive but necessary expedient, and is not likely to be mitigated in any way until power becomes available in 1957 from the hydro-electric scheme on the Lualaba River in the Congo, to which I have previously referred.

The coal and wood which thus supplies the raw material for the boilers of the power plants has to supply a power requirement of, at present, 130 megawatts. The present installed capacity of the Copperbelt is 163 megawatts with a continuous effective capacity of 135 megawatts. This requirement is increasing all the time with the advent of new mines and of greater loads by the old mines, and by 1957 the requirements of the Copperbelt will be about 196 megawatts and by 1961 will be about 220 megawatts. The generating capacity of the stations is being increased to give a continuous effective capacity of 183 megawatts, and this is considered to be the practical limit of coal-fired plants if we are to get away from total dependance on rail transport and to avoid a permanently unbalanced coal/rail position. Plans for further power are therefore based on

Charging up stope, Mufulira Mine

hydro-electric schemes and, as these come in the thermally generated power will decrease as, in fact, must be the case when we consider that some of the existing plant is getting on for thirty years of age. In 1957 it is expected that the requirements of the Copperbelt will be met as to 50 megawatts from the hydro-electric source in the Congo and 146 megawatts by thermal power based on coal and wood. In 1960 or 1961, assuming that a Rhodesian source of hydro-electric power will be available, the requirements of the Copperbelt will be met by about 150 megawatts of hydro-electric power and 70 megawatts of thermal power.

The Rhodesia Railway system is therefore a key factor in the ability of the Copperbelt to maintain full production over the next few years. In addition to carrying coal for the Copperbelt, this system has to carry the exports of metals, and the present position is one which is not without some anxiety because of the ever-increasing requirements of the Federation which, for the nine years since the end of the war, appear always to have been in excess of the ever-increasing capacity of the railroads. From 1960 onwards the key to full production will be the introduction of hydro-electric power from one or other of the Rhodesian sources. For this reason the copper companies are now anxiously awaiting a decision to be taken as to which of these stations is to be proceeded with.

The other problem concerns the relationships between the European and the indigenous workers on the mines. As I have said earlier, it is obviously a matter which leads to difficulties when one establishes a highly complex modern industry, requiring the employment of highly skilled Europeans, in the middle of a primitive community which must supply the common labour. This leads naturally to the existence of two civilizations living and working side by side. The difference between the living standards and the remuneration of these two communities must create, as time goes on, an ever-increasing problem. It is clear that a European community must enjoy relatively high standards in order to attract that community at all in the first place. It is equally clear that the indigenous community is not yet ready for the enjoyment of such standards.

So far as the Copperbelt is concerned, this situation has led, with the passage of time, to an increasing tension between the two communities. The European community has become understandably concerned with the protection of its standards in the face of this potential competition from indigenous workers and increasingly anxious to safeguard its position. The African workers have over the years increasingly sought advancement, both financial and in the way of opportunity to take better and more skilled jobs.

This situation has been the subject of much thought, much discussion and much enquiry since the end of the war. The Northern Rhodesian Government from time to time has appointed Commissions to enquire into the position and to report on it. The Companies, too, have been attempting for some time to deal with the problem and to come to some agreement with the various parties concerned, some agreement which would provide reasonable safeguards for the European daily-paid employees, and at the same time satisfy the legitimate aspirations of the African workers. In May, 1953, the Companies initiated

discussions with the European Union. Negotiations proceeded throughout the rest of 1953 and, in January 1954, the discussions were expanded into four-party talks between the Companies, the European Union, the European Staff Association and the African Union. These talks proceeded for another six months but, unfortunately, in July, 1954, the talks broke down, whereupon the Northern Rhodesian Government immediately announced the setting up of another Board of Enquiry, this time under the chairmanship of Sir John Forster, K.B.E., Q.C. This Board sat in September, 1954, and heard evidence from the Companies, the European Union, the Staff Association and the African Union, and the Board published its Report last October. This Report analysed the arguments put forward by the various parties and came to the conclusion that a solution of the problem rested with those in the industry, and it added that it regarded an early settlement of this question as imperative. Promptly after publication of this Report the Companies again initiated discussions with the European Union and these discussions are still proceeding.

I believe that there is a real understanding on all sides of the important issues involved and a genuine willingness to reach some agreement. It is no secret that a solution of this problem is regarded by most people, both within and without the industry, as the most urgent matter facing the Copperbelt and perhaps the Federation of the Rhodesias and Nyasaland, based as it is on the policy of partnership between the races. I must confine my remarks to-day to the generalities I have given you already. For one reason, I think that to go into details would be out of place in an address of this sort and for another reason, as I have already said, negotiations are under way in Rhodesia and I do not think it would be proper of me to say more than I have done already.

It remains to give my opinion as to the outlook for this industry. If we assume, and I suggest must assume, that the two main problems which I have mentioned, namely, the supply of power to the Copperbelt and the question of the future relationships between European and African workers, will be resolved in the near future, we shall then have the prospect of an industry which is already the second biggest copper producing industry in the world, growing from strength to strength with the possibility that within the lifetime of some of us it may become, together with the Congo, the main producing field in the world. In many respects the position is almost ideal. Here we have communities living, by reference to their own standards, under conditions which would be hard to find elsewhere. It has many favourable technical factors, such as the grade of the ores and the continuity and long life of the mines, which enable all planning to be on more or less a semi-permanent basis. Yet, the history of the non-ferrous metal world is that the industry will experience years of slump and years of prosperity. It is so long since this industry experienced years of slump that there are few people in the industry to-day who have recollections of that. Consequently, there is perhaps a marked absence of cost consciousness in this industry, and this is one of the factors which perhaps has to be carefully assessed. The costs in Rhodesia are undoubtedly increasing all the time. Mining at greater depths, tramming and hoisting longer distances, pumping from greater depths, the falling off of grade in some mines

as the depths get greater, all these factors are adding to the costs each year on purely technical grounds. Furthermore, in many of the other factors of cost there is a continuing process of inflation. These large communities, with their large European and African townships, cost an increasing amount to maintain each year. The cost of power and of railroad transportation is increasing. The rising standard of living for Africans, which the industry can point to with pride and which indeed is one of its main civilizing achievements, must cost more as time goes on unless it is accompanied by increased productivity, mechanization and efficiency. All these factors give room for thought as to the competitive position of this industry within the world copper picture.

There are, however, two other factors which argue favourably for Rhodesia. One is that similar processes are occurring in some of the other copper-producing fields of the world; the other is that in the total cost of production of the Rhodesian mines there is a very large element of variable cost, represented principally by the royalties payable. These royalties are based on the price of copper, and therefore if the price of copper were to fall drastically this element would also fall drastically, and thereby provide a certain amount of cushion in bad times. There are other elements of this sort, and these tend to make the cost of production in Rhodesia somewhat difficult to compare with those of other producing fields.

This concludes my address. It only remains for me to thank you, Mr. Chairman, for presiding here to-day and to express the hope that, as the first High Commissioner for the Federation in London, you will not disagree when I give it as my opinion that the copper mining industry of Northern Rhodesia, with its revolutionary effect on the finances of Central Africa within one generation, has been the biggest single factor leading to the creation of this Federation, with all its promise for the future of Africa and, indeed, for the future of the United Kingdom.

DISCUSSION

SIR SELWYN SELWYN-CLARKE, K.B.E., C.M.G., M.C. (Chairman of the Commonwealth Committee): I had been looking forward with eager expectation to meeting Mr. Prain and to listening to his lecture, and my hopes have been fully realized. There were two main reasons for my eagerness. Some twenty years ago I was invited to visit the Roan Antelope Group and I was very impressed with the work that was being done by the mine managements for the welfare of their employees. Many of the Africans were living in houses with their families and appeared to me to be a happy and contented lot, very different from their fellows whom I saw later in the rather soulless bachelor compounds attached to the Rand gold mines. Secondly, I had studied Mr. Prain's address to the joint meeting of the Royal African and Royal Empire Society in November of 1953, and I had realized what a fund of wisdom and foresight he had brought to bear on the problem of advancement of Africans on the Copperbelt. As you probably know, Mr. Prain has the enviable reputation of being a practical idealist—although he would modestly say that he is a realist rather than an idealist. In his capacity as Chairman of the Rhodesian Selection Trust he was responsible for the very generous endowment of some £80,000 for a Chair of Race Relations at Oxford. I am sure that I shall be voicing the desires of my colleagues in

the Commonwealth Section of the Royal Society of Arts and indeed of all those present here this evening when I say that our good wishes go with him in his heavy task of smoothing over the very real difficulties of the Copperbelt arising from the courageous notice of cancellation of the agreement of the European mine workers on 4th November last and to my mind the unhappily conceived strike of the African labourers on the 3rd January of this year.

I should like to ask four questions. In view of the importance of the copper-mining industry to Northern Rhodesia and to the Commonwealth, and of the Government's known interest in the welfare of both European and African workers, can the lecturer tell us whether it is likely that the Federal Government will take an active part, if need be, in helping to secure peace within the industry just as our own Government to-day is endeavouring to secure peace in the railway dispute?

Secondly, would it not be fair to Sir Malcolm Watson to associate his name with the pioneer anti-malarial work in Malaya? Mr. Prain did mention the name of Sir Ronald Ross who, of course, earned a world-wide reputation, but I do feel that Sir Malcolm Watson should be mentioned too in that connection. Thirdly, in view of the importance of forests in soil and water conservation, is replanting and re-afforestation taking place concurrently with the clearing of the 200 square miles of forest? Lastly, is there a likelihood of the Kafue and Kariba hydro-electric schemes, which were described to us by Sir William Halcrow in our last Session, being pressed forward to meet the power and thermal requirements of the mines?

THE LECTURER: The first question was whether the Federal Government might take an active part in maintaining peace in the industry. In reply, I think that under the constitution, if that is the right word, of the Federation certain subjects are reserved for the territorial governments and certain other subjects are reserved for the Federal Government. Labour and mines are reserved for the Territorial Government and therefore they are matters for the Northern Rhodesian and not the Federal Government. So if I may re-phrase the question, it would be 'Would the Northern Rhodesian Government be likely to take an active part . . .?' All I can say is that the Northern Rhodesian Government set up a Board of Enquiry under Sir John Forster. As I mentioned earlier, that Board among its conclusions said that in its opinion the solution of this problem rested squarely on the shoulders of those in the industry. The Northern Rhodesian Government has not said anything about that report, it has merely published it, but I assume from the fact that it has not dissociated itself from the report that it agrees with that conclusion and I think I can say that we in the industry agree with it. It is a matter we feel must be settled by those in the industry. I think that the comparison with the present position in the United Kingdom is perhaps not quite accurate. I can see, for instance, that if there were prolonged strikes at any time on the Copperbelt—I am not suggesting there will be, but if there should be—to a point where the revenues were seriously prejudiced, then I think, and I am giving here my own opinion, that it is conceivable that the Federal Government might say that it is now within their province because finance is within their province; but that has yet to be tested.

I am very glad you raised the question of Sir Malcolm Watson. I would have mentioned the name of Sir Malcolm Watson except that I know how modest he is and how he insists that it was Sir Ronald Ross who was responsible for the discovery of the carriers of malaria. It was true that it was Sir Malcolm Watson who converted that discovery into a practical application. It was Sir Malcolm Watson who laid out the control programme for the Copperbelt. He was himself consultant to the Copperbelt on this and we do owe him an immense debt of gratitude. The control of malaria in the Copperbelt has been described as one of the three great tropical hygiene achievements in the world. I would like to include his name in this connection with that of Sir Ronald Ross.

With regard to the question of re-afforestation, the position is that the forests which are being cut are cut by consultation with the Forestry Department of the Northern Rhodesian Government. It is the Northern Rhodesian Government which is responsible for re-afforestation and it is proceeding to re-afforestate, but it cannot, of course, do so at the speed at which we are cutting. Nor are all the areas suitable for re-afforestation, but the Government is attempting to use this opportunity to get some real plantations going.

Are the Kafue and Kariba schemes being pressed forward? Well, they are being pressed forward by those in the industry and by the various boards that have been asked to advise on this, but Sir Godfrey Huggins announced only two days ago that no decision can be taken for some time because there are some very important factors still to be taken into consideration. I said in my address that we are watching that position with some anxiety, and I think that is correct, because we feel that unless this decision is taken within the next two or three months at the latest we may be short of power in the Copperbelt in 1960. I can only say I think the Federal Government is aware of the urgency of this and we hope it will take a decision very soon.

MR. J. P. MCDONAGH: In view of the apparent difference in attitude between the two mining companies to this interesting question of the advancement of Africans in the mining industry, it appears to me as an outsider rather naive that the African Mine Workers Union decided to strike at the beginning of this week for an increase in basic pay rather than to pledge their support to the mining group which to them must appear the more liberal. I would welcome Mr. Prain's comments, unless he feels the matter is *sub judice*.

THE LECTURER: I have to be very careful what I say. I have had experience of this before and I find that anything I might say is in the *Northern News* out there before it is in the *Evening Standard* here! I do not think I would like to answer that question publicly. I think I can agree that an African strike at this time is unfortunate, but I would like to make clear that it is a strike entirely connected with advancement for money, it is a wage strike, and has nothing to do with advancement in the sense which we have been using.

MR. P. W. HODGENS: Would Mr. Prain like to comment on the transport position? As I understand it and as he has said, there is at the moment a difficult situation in moving enough coal north from Wankie, and as copper-producing capacity goes up, as he suggests it will, this will become a much more urgent problem than it is at the moment. I for one know of no plan of railway development which seems likely to enable the full coal demand of the Copperbelt to be met.

THE LECTURER: I think there is plenty being done about getting the transport position right. I did say in my Annual Report, in my speech to the shareholders, that I thought we were now paying the penalty for lack of decisions in the past. I found that was very badly misinterpreted locally: they thought I was making attack against the present administration and against the railway workers. I would like to say that I think the present administration under Sir Roy Welensky as Minister of Transport is doing a fine job trying to get it right, and I think the railway workers are doing a fine job, but they are not starting from scratch on this at all and they have got a lot of leeway to make up. It is a difficult, complex problem, and I think I must confine myself to saying that it is the key to our ability to produce copper until 1959 or so, and that it is a very big problem because our requirements of coal will not go down very much when we start getting power from the Belgian Congo. I think

they are fully aware of this problem and they are doing their best to meet it under rather difficult conditions.

MR. R. C. DENING: In view of research developments in this country, has any consideration been given to the use of atomic power as a way round the hydro-electric and coal problems?

THE LECTURER: I do not know whether Mr. Dening has read an extremely interesting article on this by Professor Bronowski in the last issue of *Optima*, 'Atomic power in relation to mines'. He points out, and I agree, that if atomic power is to have industrial uses, which obviously it will have, it will be *par excellence* the way of getting power to isolated places like mining camps throughout the world. He believes, and I am inclined to agree with him, that it may have a very great application to the Copperbelt, but I do not think we can do more than say that we are watching these developments very closely. Atomic power may well prove to be a godsend to the Copperbelt—not only to replace the existing sources, but to enable us to increase electrification to a scale which we simply cannot begin on to-day: things like electric smelting and so on, which consume vast quantities of power, we probably could not do even with hydro-electric schemes, but we might with atomic power if we could get it.

SIR ERNEST GOODALE, C.B.E., M.C. (a Vice-President of the Society): Is there an assured market for this expanding output?

THE LECTURER: The answer is no.

MR. G. VIVIAN DAVIES: Is the position at the Wankie Colliery any better than it has been in recent years? I heard that there was a good deal of trouble there; I should like to enquire if the position is now happier.

THE LECTURER: Yes, it is very much happier. Wankie went through a very difficult time at the beginning of last year, a very unfortunate time with trouble in the workings, all of which has been overcome and everything there is much better—production, the conditions for workers, and so on. To-day Wankie is producing 107 per cent of the requirement for the Federation and in my opinion will be able to keep ahead of any requirements on it.

THE CHAIRMAN: I think you would like me on your behalf and on my own to thank Mr. Prain very warmly for the very interesting and very informative address that he has given us this evening. We are indeed greatly indebted to him for his most comprehensive description of the Copperbelt and for his most interesting exposition of the Copperbelt problems.

He referred to the very important part that the copper-mining industry has taken in the development of Northern Rhodesia and he has referred also to its place in the Federal economy. I from my own personal knowledge know how much Northern Rhodesia and its development owe to the copper-mining industry. When I went there in 1948 the annual revenue was round about £6 million; when I left in 1953 it was over the £30 million mark, and that increase in revenue was very largely due to the development of the copper-mining industry and, of course, the better price for copper. When the Minister of Finance in the Federal Government turns over on a restless night he must feel rather happy at some of the figures which Mr. Prain has mentioned to us to-night. He said that the profits of the copper-mining industry before taxation amount to £40 million a year, that the copper reserves of the existing

mines, the developing mines, and the mines still to be developed, amount to 15 million tons of copper. This at the average of, say, £250 per ton, comes to £3,750 million. Now a figure of that sort must I think send the Minister of Finance off into a very comfortable sleep again.

Mr. Prain also referred to the use of wood instead of coal for the Copperbelt. One point that I think should be realized in that connection is this. Not only does the use of wood mean very much higher production costs for the copper mines, but it also means that 7,000 Africans are being used for that particular job who might be used in other productive ways, since the shortage of labour at times in Northern Rhodesia is very acute.

Reference has been made to the railways. Now the picture there is not altogether as black as it has been. I think the figure of transportation of coal for November was the best there has been for some considerable time, and something like 290,000 tons of coke and coal were carried by the railways in November as compared with a figure of about 225,000 to 240,000 tons a few months earlier. The Ministry of Transport is very much alive to the situation and the suggestion that came from the back of the hall that the railways are doing very little to improve the situation is not one, I think, that the railways administration would accept for a moment. The short fact is that the railways have been very short of staff, of locomotives, and of wagons, and that these shortages are being fairly rapidly made good.

There is only one point I would mention with regard to the Kariba and Kafue statement that Sir Godfrey Huggins made when he had to announce that it was not possible for the Federal Government to make a decision at this time: he added that the delay involved would not prejudice the question of satisfying the estimated power short-fall on the Copperbelt in a few years time. I think that must give the copper-mining companies such satisfaction as they can extract from his statement.

I do not propose to refer to-night to this very difficult problem of the advancement of the African in the copper-mining industry. The problem is still under discussion, as Mr. Prain has stated, and I think all I can do to-night is to express the hope, as so many of us have done, that the desire of all parties to reach an equitable solution will be reflected sooner rather than later in an agreement that is acceptable to all parties.

I would once more reiterate how deeply we are indebted to Mr. Prain for his most interesting address, which has given us all so much clearer a picture of the Copperbelt of Northern Rhodesia and its problems.

The vote of thanks to the Lecturer was carried with acclamation; and, another having been accorded to the Chairman, the meeting then ended.

A collection of recent colour photographs illustrating aspects of life in the Copperbelt was shown in the Library in connection with this lecture.

CORRESPONDENCE

'THE USE OF TYPE'

From JOHN R. BIGGS, A.T.D., BRIGHTON COLLEGE OF ART AND CRAFTS, GRAND PARADE, BRIGHTON, 7.

In the review of my book *The Use of Type*, published in the last issue of the *Journal*, Mr. Michael Oliver states, among mostly fair comment, that there seems to be no justification for suggesting the use of small capitals, or ordinary Roman capitals, with italic lower-case. My reply is that the use is justified by the practice of fine typographers for four and a half centuries, from Aldus Manutius (I have one of his books before me as I wrote) and Taglienti to Bruce Rogers and our own Sir Francis Meynell. Many examples of text set in italic lower-case with Roman (that is, upright) capitals are to be found in Stanley Morison's *Four Centuries of Fine Printing*, and the same practice is evident in the Nonesuch Dante. Sloped Roman capitals (which we now regard as inseparable from italic lower-case) do not appear to have become popular until about the middle of the sixteenth century.

Eric Gill in his *Essay on Typography* stresses that there are three basic latin alphabets, upright capitals, lower-case, and italic lower-case, many of the letters having quite different shapes as A a *a*. But what we call italic capitals are really sloped Roman capitals, the scribes usually using upright capitals with the sloping (italic) lower-case.

The reviewer, Mr. Michael Oliver, writes as follows:

The sentence in my review which Mr. Biggs quotes was intended as an expression of opinion on modern typographical usage, but I have certainly made it appear too categorical. By using the word 'seems' it was intended to convey that this was an opinion, but I should also have inserted the word 'to-day'.

Mr. Biggs very rightly sets out historical (and some modern) examples of the use of upright capitals with italic lower-case, and indeed, reproductions of an early italic, usually the Aldine, showing this use, appear in practically every book on the history and the art of printing. What I had in mind, however, was that in my view the fact that this combination was used in the past is not relevant, except in very special circumstances, in the different conditions of to-day, and certainly does not justify the combination being included, as it was in *The Use of Type*, in a paragraph giving the more normal combinations such as capitals with small capitals and so on.

My objection is based on the history of italic as a type face, and through this on considerations of appearance, since the forms are in part conditioned by their precursors, and the way in which we see them is conditioned by their familiarity, or otherwise, to us. This is clearly too wide a subject to enter into fully here.

FROM THE JOURNAL OF 1855

VOLUME III. *16th February*, 1855

IMPORTANT TO HECKLERS

The following letter was quoted in a letter written by Mr. John Smart in the *Dundee Advertiser*.

'Dr. Elliot, of Carlisle, having seen in the *Journal of the Society of Arts* a communication signed John Smart, Dundee, respecting Industrial Pathology, and asking for suggestions to protect flax-dressers against the effects of the stour inhaled during work, has to offer an infallible and ready safeguard against the very serious evil complained of. The remedy is to adjust a slight frame of copper wire to the face, including the nose and mouth, leaving the eyes free; cover this frame with wire

gauze of large mesh, and over all sew a ply of thin silk; let this mask fit close round the edges and under the chin, and stand off from the mouth and nostrils an inch or more, and let the wearer be utterly indifferent to the novel appearance, and he may work amid all the stour of all the flaxmills of Dundee and breathe as pure an air as if no stour existed. Such a mask will enable the wearer to work the finest building stone with impunity, or to go through the dense smoke of a conflagration breathing freely while the unprotected are choking.'

Mr. Smart continued:

I therefore lost no time in personally testing the efficacy of the protector, and I am happy to say that the result exceeds my most sanguine expectations, for it would be difficult to find words to express the comfort and benefit I have derived from it. And I am aware, Mr. Editor, that there are very many in a community such as this to whom the adoption would be most invaluable, and it is for this reason that I have requested you to give this publicity. Trusting that the importance of the subject will be deemed a sufficient apology for trespassing on your valuable space, I am your obliged.

JOHN SMART

Some Activities of Other Societies and Organizations

MEETINGS

MON. 21 FEB. Electrical Engineers, Institution of, Savoy Place, W.C.2. 5.30 p.m. C. G. Forsberg and G. G. MacNeice: *The Recent Search for the Salvage of the Comet Aircraft near Elba.*

Geographical Society, Royal, South Kensington, S.W.7. 5 p.m. A. A. L. Caesar: *Economic Planning of Eastern Europe.*

Imperial Institute, South Kensington, S.W.7. 5.45 p.m. Kenneth Bradley: *Exploring the Islands: Falkland Islands.*

Petroleum, Institute of, 26 Portland Place, W.1. 5.30 p.m. F. Leicester: *The Modern Planning of Regional Surveys for Petroleum.*

TUES. 22 FEB. Civil Engineers, Institution of, Great George Street, S.W.1. 5.30 p.m. (1) A. M. Muir Wood: *Folkestone Warren Landslips 1948-1950 Investigation*; (2) N. E. V. Viner Brady: *Folkestone Warren Landslips: Remedial Measures, 1948-54.*

Manchester Geographical Society, 16 St. Mary's Parsonage, Manchester, 3. 6.30 p.m. Prof. C. W. Wardlaw: *Borneo.*

Textile Institute, at 10 Blackfriars Street, Manchester, 3. 7 p.m. N. H. Chamberlain: *Electronic Aids to Better Production.*

WED. 23 FEB. British Kinematograph Society, at G.B. Theatre, Film House, Wardour Street, W.1. 7.15 p.m. R. Robertson: *The Cinema Screen.*

Electrical Engineers, Institution of, Savoy Place, W.C.2. 5.30 p.m. A. Rusck: *High-Voltage Transmission Developments in Sweden.*

Italian Institute, 39 Belgrave Square, S.W.1. 6.30 p.m. Dr. Nicolai Rubinstein: *Italian Cities of the Middle Ages and the Renaissance—Venice.*

Locomotive Engineers, Institution of, at the Institution of Mechanical Engineers, 1 Birdcage Walk, S.W.1. 5.30 p.m. G. Foster: *Welding of Steel or Cast Iron Components in Locomotive Manufacture and Maintenance.*

Royal Central Asian Society, at the Royal Society, Burlington House, Piccadilly, W.1. 1.30 p.m. Brig. S. H. Longriff: *Middle East Oil: Blessing or Curse?*

Victoria & Albert Museum, South Kensington, S.W.7. 6.15 p.m. Iolo Williams: *The Origins of English Landscape Drawing.*

THURS. 24 FEB. Refrigeration, Institute of, at the Institution of Mechanical Engineers, 1 Birdcage Walk, S.W.1. 5.30 p.m. G. Yate Pitts: *Sub-soil Temperatures and Frostheave.*

FRI. 25 FEB. Engineers, Junior Institution of, at Pepys House, 14 Rochester Row, S.W.1. 7 p.m. H. W. D. Hughes: *Some Stages in the Refining of Crude Oil.*

SAT. 26 FEB. Horniman Museum, London Road, Forest Hill, S.E.23. 3.30 p.m. T. W. Bagshawe: *Disappearing Country Occupations.*

MON. 28 FEB. Imperial Institute, South Kensington, S.W.7. 5.45 p.m. Sir Phillips Raffray: *Exploring the Islands: Mauritius.*

TUES. 1 MAR. British Architects, Royal Institute of, 66 Portland Place, W.1. 6 p.m. Dr. J. Bronowski: *Architecture as a Science and Architecture as an Art.*

Civil Engineers, Institution of, Great George Street, S.W.1. 5.30 p.m. J. P. Stott: *Prestressed Concrete Roads.*

Electrical Engineers, Institution of, Savoy Place, W.C.2. 5.30 p.m. (1) Prof. F. Brailsford and C. G. Bradshaw: *Iron Losses at High Magnetic Flux Densities in Electrical Sheet Metals*; (2) C. D. Mee and R. Street: *An Improved Precision Permeameter.*

Manchester Geographical Society, 16 St. Mary's Parsonage, Manchester, 3. 6.30 p.m. Prof. T. H. Oliver: *Adriatic Holiday.*

WED. 2 MAR. Petroleum, Institute of, 26 Portland Place, W.1. 6 p.m. N. E. F. Hitchcock: *Additives—their Functions Explained.*

Victoria & Albert Museum, South Kensington, S.W.7. 6.15 p.m. Helen Lowenthal: *Landscape in Victorian Art.*

THURS. 3 MAR. Electrical Engineers, Institution of, Savoy Place, W.C.2. 5.30 p.m. G. L. E. Metz: *The Electrical Engineering Industry in the Post-War Economy—II.*

Metals, Institute of, 4 Grosvenor Gardens, S.W.1. 6.30 p.m. W. E. Hoare: *Tin and Tinplate.*

SAT. 5 MAR. British Interplanetary Society, at Caxton Hall, Caxton Street, S.W.1. 6 p.m. R. C. Jennison: *The Radio Exploration of Space.*

Horniman Museum, London Road, Forest Hill, S.E.23. 3.30 p.m. Glyn E. Daniel: *The Megalith Builders.*

OTHER ACTIVITIES

MON. 21 FEB. UNTIL SUN. 27 FEB. Imperial Institute, South Kensington, S.W.7. 12.30 p.m., 1.15 p.m. and 3 p.m. Weekdays, 3 p.m. and 4 p.m. Sats., 3 p.m., 4 p.m. and 5 p.m. Suns., Films: *Down in the Forest—Australia: Magic of Nassau—Bahamas.*

MON. 28 FEB. UNTIL SUN. 6 MAR. Imperial Institute, South Kensington, S.W.7. 12.30 p.m., 1.15 p.m. and 3 p.m. Weekdays, 3 p.m. and 4 p.m. Sats., 3 p.m., 4 p.m. and 5 p.m. Suns., Films: *People's Land—United Kingdom: Nassau Reflections—Bahamas.*

NOW UNTIL 12 MAR. Sanitary Institute, Royal, in the Museum of Hygiene, 90 Buckingham Palace Road, S.W.1. Exhibition: *You versus Pests—Insects that Attack Food and Endanger Health.*

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